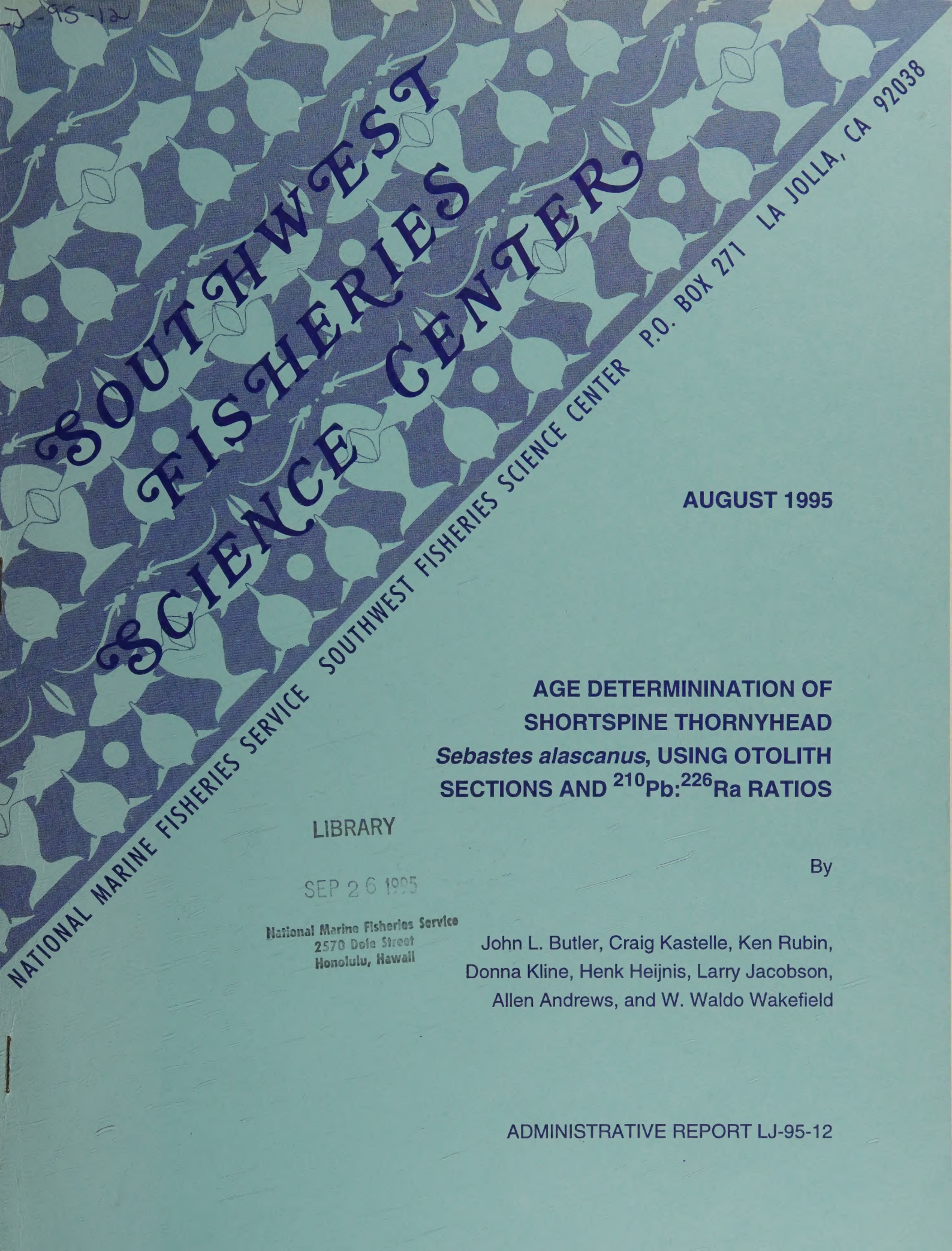




LJ-95-12

**SOUTHWEST
FISHERIES
SCIENCE CENTER**

NATIONAL MARINE FISHERIES SERVICE SOUTHWEST FISHERIES SCIENCE CENTER P.O. BOX 271 LA JOLLA, CA 92038

AUGUST 1995

**AGE DETERMINATION OF
SHORTSPINE THORNYHEAD
Sebastes alascanus, USING OTOLITH
SECTIONS AND ^{210}Pb : ^{226}Ra RATIOS**

LIBRARY

SEP 26 1995

National Marine Fisheries Service
2570 Dole Street
Honolulu, Hawaii

By
John L. Butler, Craig Kestelle, Ken Rubin,
Donna Kline, Henk Heijnis, Larry Jacobson,
Allen Andrews, and W. Waldo Wakefield

ADMINISTRATIVE REPORT LJ-95-12

This Administrative Report is issued as an informal document to ensure prompt dissemination of preliminary results, interim reports and special studies. We recommend that it not be abstracted or cited.

**AGE DETERMINATION OF SHORTSPINE THORNYHEAD, *SEBASTOLOBUS*
ALASCANUS, USING OTOLITH SECTIONS AND ^{210}Pb : ^{226}Ra RATIOS**

by

John L. Butler¹, Craig Kestelle², Ken Rubin³, Donna Kline⁴, Henk Heijnis⁵,
Larry Jacobson¹, Allen Andrews⁴, W. Waldo Wakefield⁶.

¹ Southwest Fisheries Science Center, P. O. Box 271, La Jolla, CA 92038

² Alaska Fisheries Science Center, Seattle, WA 98115

³ Scripps Institution of Oceanography, La Jolla, CA 92037

⁴ Moss Landing Marine Laboratories, Moss Landing, CA

⁵ Australian Nuclear Science and Technology Organization

⁶ Institute of Marine and Coastal Science, Rutgers University, New
Brunswick, NJ

Abstract.

Annuli in thin and break and burn sections of otoliths were counted to determine the age of the shortspine thornyhead, *Sebastolobus alascanus*. Inter-reader comparison revealed high variability, but readers agreed that shortspine thornyheads were old. Otolith counts indicated longevity of at least 100 years. Age estimates were validated using ^{210}Pb : ^{226}Ra ratios in the cores of otolith. Radiometric dating indicate that ring counts may overestimate age but are inconclusive and subject to bias. Despite uncertainties, all approaches indicate that shortspine thornyhead is a very slow growing, long-lived fish.

Introduction

Counts of thin sections or charred otolith sections are now the accepted technique long-lived species (Beamish and McFarlane 1987). We used both thin sections and break and burn preparations of otoliths to estimate the ages and longevity of shortspine thornyhead. Annuli counts indicate that shortspine thornyhead are very long lived, but age estimates may be misleading because annual marks are difficult to count. We therefore used radiochemical approaches (^{210}Pb : ^{226}Ra ratios) to validate age estimates from thin sections (Bennett et al. 1982, Campana and Zwanenberg 1990, and Fenton et al. 1990).

Radiochemistry - Background.

The radiochemical dating of calcium carbonate structures such as otoliths is based on the $^{238}\text{Uranium}$ decay series. ^{238}U is the most abundant naturally occurring isotope of uranium. It decays through a series of short-lived daughter isotopes to $^{230}\text{Thorium}$ and then to $^{226}\text{Radium}$. Thorium is absorbed by particulate matter and is relatively depleted in open ocean waters relative to sediments. This is important

because shortspine thornyhead larvae may spend up to one year in the plankton. As a result, the core of the otolith may have different levels of radium than the rest of the otolith. $^{226}\text{Radium}$ is a chemical analogue of calcium and is incorporated into the otolith. $^{226}\text{Radium}$ decays through the short lived daughter isotope $^{222}\text{Radon}$ to ^{210}Pb (Lead). Radon is a gas that may diffuse through porous structures. The loss of $^{222}\text{Radon}$ is a potential source of error particularly when ageing to small otoliths and leads to underestimates of ages.

Radiochemical age validation work for shortspine thornyheads was based on ratios of $^{210}\text{Pb}/^{226}\text{Ra}$ measured in otoliths. The ratio of ^{210}Pb to ^{226}Ra approaches equilibrium asymptotically with time (Figure 1) and is therefore most useful for structures less than 100 Y old. The method assumes that negligible amounts of ^{210}Pb are incorporated into the otolith structure when it is formed.

In order to increase sample size and to obtain information about the repeatability of results, we used thin section and break and burn ages from several readers and a large number of radiochemical estimates. Unfortunately, neither annuli counts nor radiochemical approaches gave

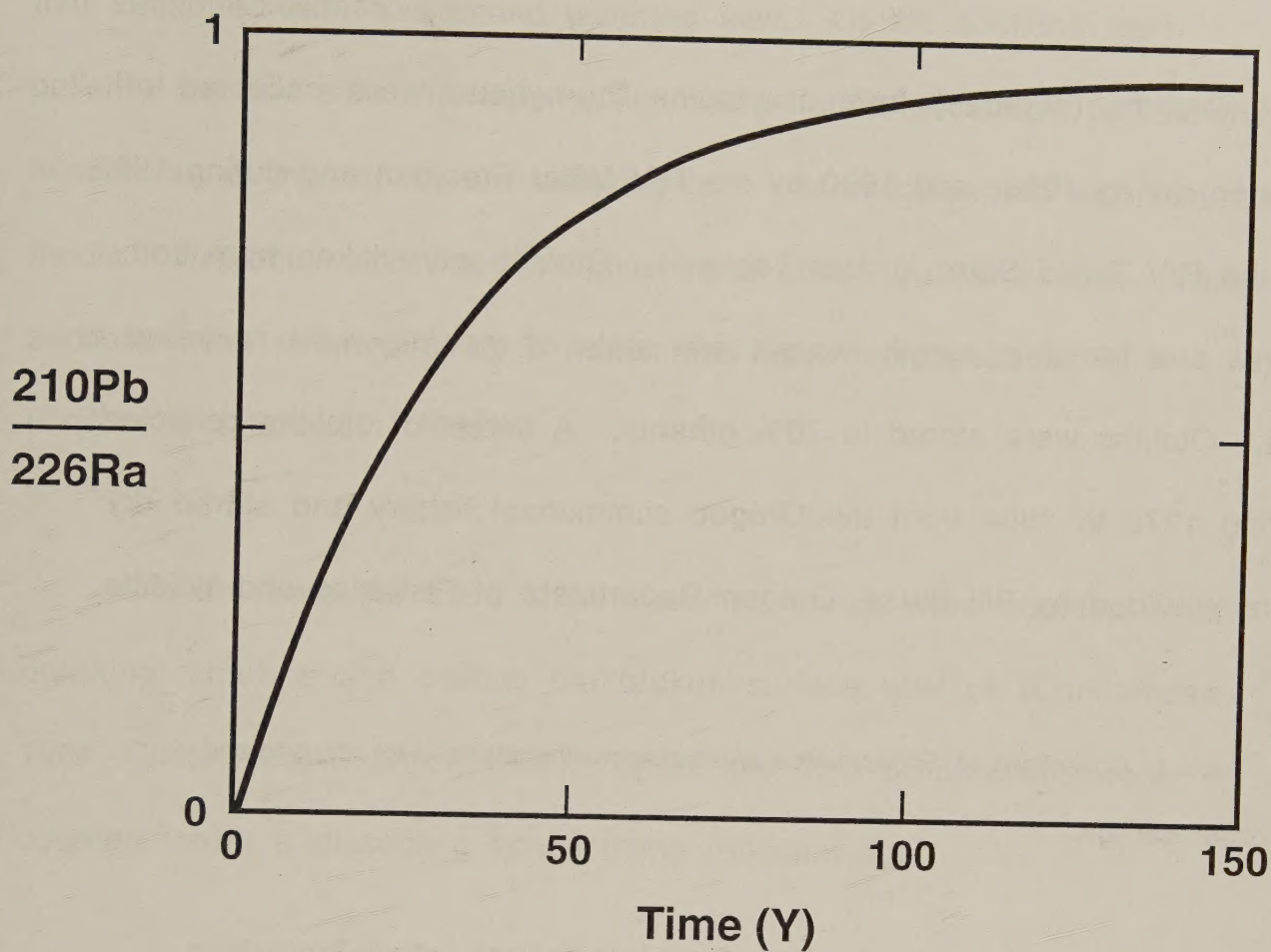


Figure 1. Ratio of the activities of ^{210}Pb and ^{226}Ra during first 150 years from initial condition, where the initial condition is no ^{210}Pb and 100% ^{226}Ra .

unambiguous results.

Materials and Methods

Otoliths (sagittae) from shortspine thornyhead were collected off Oregon during 1988 and 1990 by the R/V Miller Freeman and during 1989 by the R/V David Starr Jordan (Table 1). Otoliths were taken from both males and females; length, weight and state of maturity were recorded at sea. Otoliths were stored in 70% ethanol. A series of otoliths collected during 1979 to 1984 from the Oregon commercial fishery and stored dry were provided by Bill Barss, Oregon Department of Fisheries and Wildlife.

Table 1. Collections of *Sebastolobus alascanus* otoliths analyzed for ring age and radiochemical age.

Sample	Number	Year	South Latitude	North Latitude	Preparation
Oregon Dept. Fish and Game	62	1979-87	43° N	44° N	Thin Section
D. S. Jordan 8903	200	1989	40° 08'N	45° 10'N	Thin Section
Miller Freeman 8809	884	1988	44° 07'N	45° 20'N	Thin Section
Miller Freeman 9008	30	1990	44° 03'N	45° 32'N	Thin Section
Miller Freeman 9011	582	1990	44° 31'N	41° 35'N	Break & Burn

No difference in size or weight was found between right and left sagittae, and sagittae were chosen at random for thin sectioning. Otoliths collected in 1979 - 1989 were embedded in polyester casting resin and thin sectioned with a diamond wafering saw. Otolith sections were polished on one side with lapping film using double stick tape to hold the section on a fingertip before adhering to a microscope slide with mounting media. The other side was then polished to obtain a clear section. Thin sections were counted using a transmitted light microscope at 50 X (Chilton and Beamish, 1982).

Otoliths from the 1990 Miller Freeman cruise were counted after breaking, charring and coating the broken surface with oil (Christensen 1964, Chilton and Beamish 1982). Break and burn preparations were counted under a dissecting scope using reflected light.

To determine repeatability of annuli counts a series of otolith preparations were counted by several readers at different agencies. These readers included John Butler (Southwest Fisheries Science Center), Betty Goetz (Alaska Fisheries Science Center), Shelly Jay (Alaska Fisheries Science Center), Bob Mikas (Oregon Department of Fish and Wildlife) and

Shayne MacClellan (Department of Fisheries and Oceans, Nanaimo, Canada).

To compare section ages to radiochemical estimates, we grouped contralateral otoliths by section age for radiochemical dating. Cores measuring 3 x 6 mm were extracted from 30-40 otoliths using the diamond wafering blade to constitute samples of about 1 g for radiochemical analysis. Our experience indicated that 1 g was a minimum useful sample. Cores were grouped by ages at 5 and 10 year intervals. The dimension of the cores was taken from otoliths of fish aged at 5 y. This method of coring produced radiometric ages lower than annuli estimates because some material deposited after the core was included. The coring technique was refined by Kestelle. He ground each core to the exact shape of a juvenile otolith and thereby removed most of the younger material.

Radiometric age determination using ^{210}Pb : ^{226}Ra ratios is based on the assumptions that: 1) the isotopes are in radioactive disequilibrium when deposited in the otolith, ie. no lead ^{210}Pb exists in new otolith material), and 2) no radon diffuses from the otolith. Radium is the chemical analog of calcium and is incorporated in the aragonite crystal of

the otolith. After incorporation ^{226}Ra decays to ^{210}Pb , with ^{222}Rn (half-life of 3.825 d) as an intermediate. No diffusion of radon has been detected in coral aragonite (Veeh and Burnett 1982).

Radiochemical analysis of both ^{210}Pb and ^{226}Ra are difficult and require the best ultra-low level techniques. The ^{210}Pb activity was determined by alpha spectrometry of its granddaughter isotope polonium ^{210}Po which is within 5 % of secular equilibrium one year after collection. ^{226}Ra was determined using three methods. Radon gas emanation methods (Smith and Walton 1980 as modified by Bennett et al 1982) were used by Rubin, Kastelle and Kline. Four samples were analyzed using direct ^{226}Ra alpha spectrometry (Fenton et al. 1990) by Heijnes. A single radium sample was analyzed by Andrews using Thermal Ionization Mass Spectrometry (TIMS). The mean ^{226}Ra value was calculated by weighted average (Appendix 1). Radiometric ages of the cores was then determined using $^{210}\text{Pb}/^{226}\text{Ra}$ ratios.

RESULTS

AGE DETERMINATION

Ages estimated from thin sections and break and burn indicate that shortspine thornyhead are very long lived. The oldest individuals are greater than 100 y old. Growth appears to be slow. The Brodie growth coefficient of the von Bertalanffy growth curve was $K = 0.023$ and $L_{\infty} = 72.8$ cm (Fig. 2). The age of 50% maturity is about 13 y.

Between reader variability is high (Tables 2-4), but in general readers agreed that young fish were young, and that older fish were old (Table 1-3). A single specimen from the Miller Freeman 90-08 cruise was estimated to be older than 70 years by all but a single reader (Table 2).

RADIOCHEMISTRY

Radiometric estimates of age are greatly influenced by the measured levels of the parent isotope ($^{226}\text{Radium}$). Since our estimates of ^{226}Ra were variable and because this value greatly influences radiometric age,

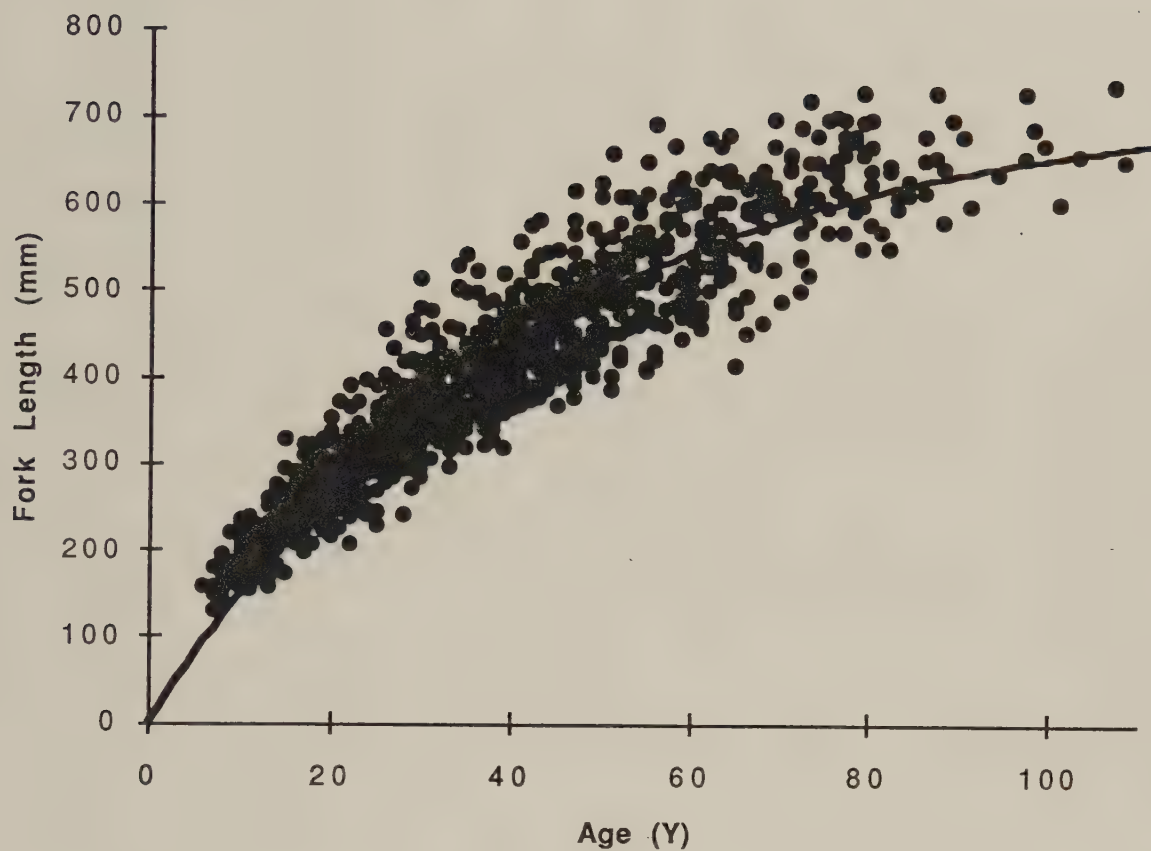


Figure 2. Age and length of shortspine thornyhead, *Sebastolobus alascanus* estimated from otolith thin sections. Fitted equation is von Bertalanffy growth model with $L_{\infty} = 72.8$ cm and Brodie growth coefficient $K = 0.023$.

Table 2. Inter-reader comparison of thin sectioned otoliths. Samples were collected on the Miller Freeman cruise 88-09.

Specimen Number	Fork Length	Readers					RANGE
		1	2	3	4	5	
88	46	42-46	38	43+/-10	34	38+/-10	34-53
96	43	89-92	44	100+/-10	106	90+/-10	44-110
113	63	60-62	71	64+/-5	71	58+/-5	60-71
156	37	22-32	32	25+/-2	31	24+/-3	21-32
217	48	93-105	57	80+/-5	97	75+/-10	57-105
295	67	71-79	83	112+/-20	139	125+/-30	71-155
299	74	133-154	89	128+/-30	116	130+/-20	89-158
300	70	52-69	99	96+/-20	116	80+/-10	52-116
436	57	44-45	63	118+/-30		105+/-20	44-115
486	27	21-23	21	26+/-5	51	25	21-51
519	38	49-70	36	55+/-10	58	48	36-65
740	39	23-27	43	70??	74	75+?	23-75
751	15	34-36	7	7(8-9)	27	9	7-36
781	33	20-29	29	60+/-20	81	59	29-81
868	41	39-49	32	33+/-5	34	36+/-2	32-49

Table 3. Inter-reader comparison of thin sectioned otoliths. Samples were collected on the Miller Freeman cruise 90-08.

Specimen Number	Fork Length	Reader						RANGE
		1	2	3	4	5	6	
1	71	90	40-60	90+/-5	75	74+/-3	89	40-95
6	30	33	14+/-2	33+/-2	34	32+/-2	31	12-35
19	21	9	8+/-1	9+/-1	7	8+/-1		7-10
22	28	16	11+/-1	20+/-2	16	6		6-22
23	24	17	12	12-13	14	13		12-17
29	18	6+	7	5+/-1	13	5-6		5-13
30	17	8+	5	7+(8)	8	8		5-8
36	10	2	3	2(3)	2	2		2-3
37	42	57-63	40+/-5	75+/-5	56	65+/-5		35-80
38	32	24-27	26+/-5	30+/-4	37	26+/-2		21-37
40	35	28-33	17+/-3	33+/-3	35	21-24		14-36
55	21	8	11+/-2	10+/-3	12	10		8-13
67	16	7+	7	7	7	6+		6-7
76	13	5+	6	5+	5	4+		4-6
79	8	2+	3	3(2)	2	2+		2-3

Table 4. Inter-reader comparison of break and burn otoliths. Samples were collected on the Miller Freeman cruise 90-08.

Specimen Number	Fork Length	Reader						RANGE
		1	2	3	4	5	6	
1	71	86	58	87+/-3	71	74+/-3	70-71	58-90
6	30	35-37	21	35-36	32	35	34-36	21-37
19	21	7-8	8	9	7	7(8)	8-9	7-9
22	28	15-18	14	13-14	14	14+/-1	16-17	13-17
23	24	12-13	12	13	11	13(14)	12-13	11-14
29	18	6	7	7+	7	7(6+)	7	6-7
30	17	3-4	7	4+	4	4(5?)	4	3-7
36	10	2	2	2-3	2	2+	2	2-3
37	42	61-63	45-56	65+/-3	58	63+/-3	60-63	45-68
38	32	28-29	27-29	28+/-2	26	26+/-2	20-30	20-30
40	35	29	21	30+/-5	31	25+/-2	21-33	21-35
55	21	7	10	9+/-1	10	9+/-2	9	7-10
67	16	6	7	6+	6	6+	6	6-7
76	13	4	5	4-5	4	4+	4	4-5
79	8	2	4	2+	2	2+	2	2-4

fifteen determinations of ^{226}Ra were made using three different techniques (Table 5). The values ranged from 0.0336 to 0.070 dpm (Figure 2). The weighted mean of all samples and techniques was 0.0537 dpm (Appendix 1).

^{210}Pb measurements varied from 0.0062 to 0.0694 dpm and gave estimates of 3 years to infinity (Table 5, Figure 3).

As expected, samples cored and analyzed by Kastelle (AFSC 1-3, Table 5) gave older ages than other samples. His coring technique removed material that was deposited later in the life of the fish. Radiometric ageing, although imprecise, supports the age estimates from thin sections and break and burn preparations.

Discussion

Shortspine thornyhead otoliths are difficult to read because the otoliths are thin. Much of the growth of the otolith is along the dorsal-ventral axis. Larger otoliths have finger-like projections on the dorsal and ventral margins. Thin cross sections of the otoliths may or may not

Table 5. Pb - 210 measurements and radiometric ages of pooled cores from *Sebastolobus alascanus* otoliths.

Sample	Standard Length	Annuli		Radiometric Age				
		Mean	Range	Pb - 210	Ra - 226	Mean	Range	
JD88 - 1	22 to 30	20	19 to 21	0.0200	0.0537	14.4	10.4	27.9
JD88 - 2	31 to 45	30	28 to 32	0.0300	0.0537	25.3	17.3	69.0
JD88 - 3	46 to 60	60	56 to 65	0.0350	0.0537	32.6	21.4	inf
JD88 - 4	59 to 66	70	66 to 76	0.0390	0.0537	40.0	25.2	inf
SWFSC 1	8 to 15	5	4 to 8	0.0085	0.0537	5.3	4.0	9.0
MF90 - 1	14 to 20	10	9 to 11	0.0091	0.0537	5.7	4.3	9.8
MF90 - 2	16 to 22	15	13 to 17	0.0104	0.0537	6.6	5.0	11.4
MF90 - 3	20 to 29	20	19 to 21	0.0165	0.0537	11.4	8.3	20.9
MF90 - 4	22 to 33	25	23 to 27	0.0244	0.0537	18.7	13.2	39.9
AFSC - 1	8 to 17	6	3 to 9	0.0062	0.0474	4.3	2.9	6.3
AFSC - 2	30 to 34	34	31 to 38	0.0496	0.0671	41.7	38.1	inf
AFSC - 3	35 to 39	42	40 to 43	0.0727	0.0694	inf	inf	inf

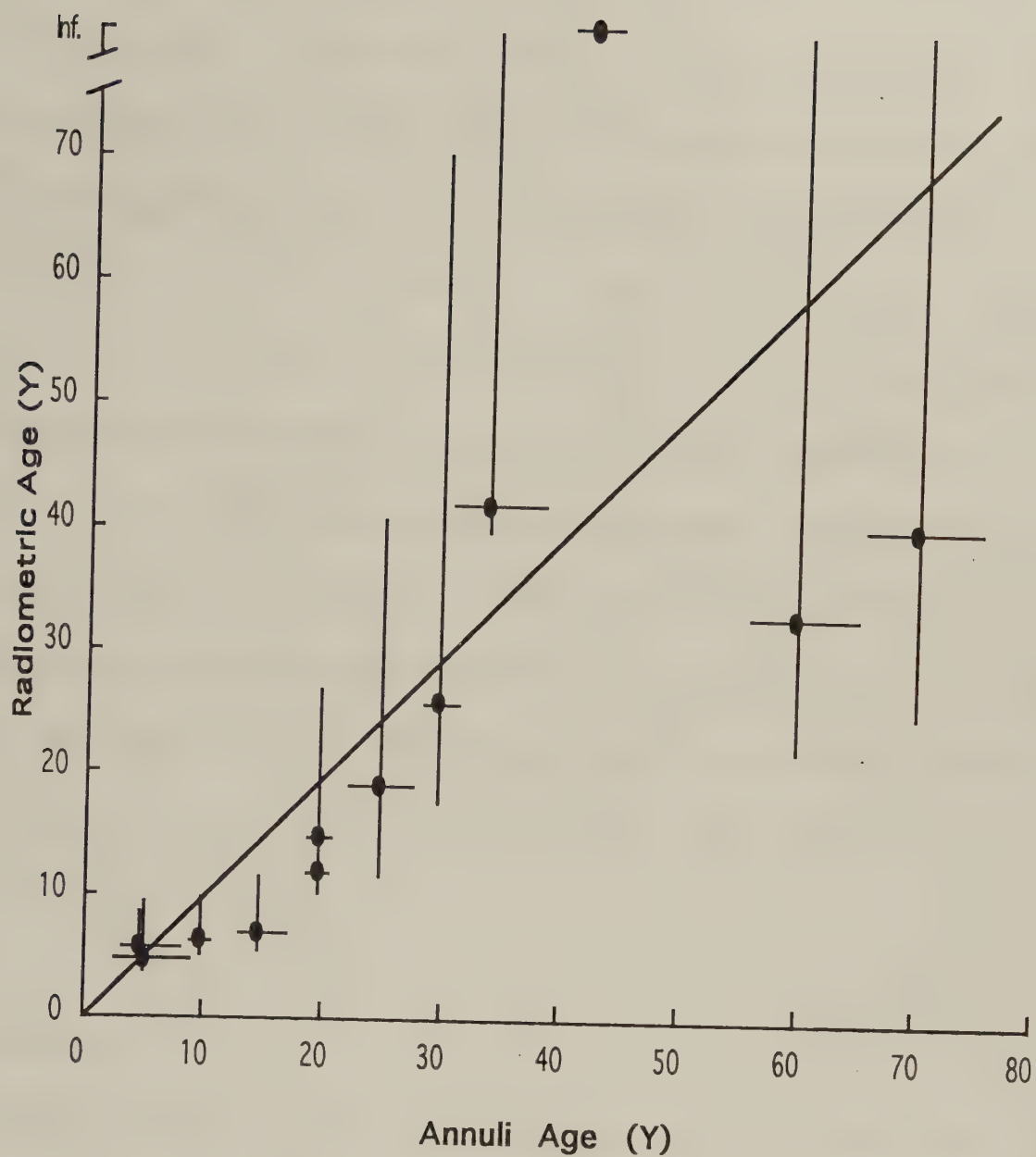


Figure 3. Radiometric and thin section estimates of the age of shortspine thornyhead, *Sebastolobus alascanus*. Error in radiometric age determined by the range of values for ^{226}Ra . Error in thin section ages estimated by range of readings among different readers.

include growth rings that are deposited in one of these projections.

Break and burn preparations suffer the same problem. Consequently, it is difficult to maintain a consistent counting path. These difficulties lead to uncertainties in age estimates and contribute to variability among readers.

Radiochemical dating supports the age estimates from conventional methods (Figure 3). Age estimates from precisely cored samples are as old or older than otolith section counts. Variability in radium estimates is a result of the limits of the techniques. TIMS promises to reduce the uncertainty in radium estimates, but unfortunately can not be used for lead determination.

Growth curve

The growth of shortspine thornyhead is very low and the fitted von Bertalanffy curve approaches the asymptote slowly. These growth rates are consistent with the habitat. Activity and growth are probably reduced by the combination of low temperature and low oxygen.

Natural Mortality

The longevity of shortspine thornyhead implies a very low rate of natural mortality. Since this fish reaches a very large maximum size (75 cm), the number of potential predators is reduced to a few large predators. Adult shortspine thornyhead inhabit the oxygen minimum zone (OMZ) where activity of all organisms is limited by the availability of oxygen ($< 0.05 \text{ ml l}^{-1}$). Large grenadiers are found below, but not in the OMZ (Adams et al. 1995). Although little is known of distribution of sleeper sharks *Somniosus* sp., their activity and foraging must also be reduced in the OMZ. Thus the OMZ may be a refuge from predation that allows organisms that can survive in that habitat to persist for long periods of time.

CONCLUSIONS

Adult shortspine thornyhead inhabit a unique environment that allows them to reach longevities in excess of 100 y. Natural mortality must be less than 0.05 per year to obtain these ages.

ACKNOWLEDGEMENTS. We would like to thank Katherine Dahlin and Angel Rodriguez for thin sectioning otoliths. Waldo Wakefield, Scripps Institution of Oceanography, and William Barss, Oregon Department of Fisheries and Wildlife provided otoliths for analysis.

Literature Cited

- Adams, P. B., J. L. Butler, W. Waldo Wakefield, Charles Baxter, Bruce Robison, Kathy. A. Dahlin and Tom Laidig. 1994. Comparisons of estimates of the abundance of slope ground fishes using ROV's and trawls. Fish. Bull. U. S. 93: 446-455.
- Allen, M. J. and G. B. Smith. 1988. Atlas and zoogeography of common fishes in the Bering Sea and Northeastern Pacific. NOAA Tech. Rep. NMFS 66, 151pp.
- Beamish, R. J. 1979. New information on the longevity of Pacific Ocean perch (*Sebastes alutus*). J. Fish. Res. Bd. Can. 36: 1395-1400.
- Beamish, R. J. and G. A. McFarlane. 1983. The forgotten requirement for age validation in fisheries biology. Trans. Am. Fish. Soc. 112: 735-743.
- Beamish, R. J. and G. A. McFarlane. 1987. Current trends in age determination methodology. In: Summerfelt, R. C. and G. E. Hall (eds.)

The age and growth of fish. The Iowa State University Press, Ames Iowa, P. 15-42.

Bennett, J. T., G. W. Boehlert, and K. K. Turekian. 1982. Confirmation of longevity in *Sebastes diploproa* (Pisces: Scorpaenidae) from $^{210}\text{Pb}/^{226}\text{Ra}$ measurements in otoliths. Mar. Biol. 71: 209-215.

Boehlert, G. W. 1985. Using objective criteria and multiple regression models for age determination in fishes. Fish. Bull. U. S. 83: 103-117.

Campana, S. E., K. C. T. Zwanenburg and J. N. Smith. 1990. $^{210}\text{Pb}/^{226}\text{Ra}$ determination of longevity in redbfish. Can. J. Fish Aquat. Sci. 47:163-165.

Chilton, D. E. and R. J. Beamish. 1982. Age determination methods for fishes studied by the groundfish program at the Pacific Biological Station. Can. Spec. Pub. Fish. Aquat. Sci. 60: 102 pp.

Fenton, G. E., D. A. Ritz and S. A. Short. 1990. $^{210}\text{Pb}/^{226}\text{Ra}$ disequilibria in otoliths of blue grenadier *Macruronus novaezelandiae*: problems

associated with radiometric ageing. Aust. J. mar. Freshw. Res. 41:
467-473.

Fenton G. E., S. A. Short, and D. A. Ritz. 1991. Age determination of orange
roughy, *Hoplostethus atlanticus* (Pisces, Trachichthyidae) using
Pb²¹⁰-Ra²²⁶ disequilibria. Marine Biology 109:197-202.

Jacobson, L. D. and R. D. Vetter. 1995. Bathymetric demography and niche
separation of thornyhead rockfish: *Sebastolobus alascanus* and
Sebastolobus altivelis. (In press)

Moser, H. G. 1974. Development and distribution of larvae and juveniles of
Sebastolobus (Pisces; Family Scorpaenidae). Fish Bull. U. S. 72: 865-
884.

Pearcy, W. G. 1962. Egg masses and early developmental stages of the
scorpaenid fish, *Sebastolobus*. J. Fish. Res. Board Can. 19: 1169-
1173.

Sandeman, E. J. 1961. A contribution to the problem of age determination

and growth-rate in *Sebastes*. Rapp. P.-v. Reun. Cons. Perm. Int.
Explor. Mer 150: 276-284.

Searle, S. R. 1971. Linear models. New York: John Wiley & Sons, Inc.

Veeh, H. H. and W. C. Burnett. 1982. Carbonate and phosphate sediments.
In: Ivanovich, M., Harmon, R. S. (eds.) Uranium series disequilibrium:
applications to environmental problems. Oxford University Press,
New York. p 459-480.

